We thank the reviewer for the helpful feedback, these suggestions have significantly improved the data and text, we are appreciative of the help and time.

We have addressed all the comments here, point by point responses to the comments are listed in BLUE.

Here we summarize the major revision in the revised manuscript:

According to the reviewers, additional filters (a 3-standard-deviation filter and a median filter) have been applied in the generated DEM to improve the DEM performance. The new DEM was also evaluated by comparing to the OIB and GNSS data, similar performances can be found (as listed in the Tables below). In particular, to account for the temporal difference between the DEM and OIB/GNSS data, when performing the comparisons we adjusted the ICESat-2 DEM elevations for the surface elevation changes between the acquisition periods of these two data. The adjustments were calculated by using the trend values derived from Smith et al. (2020) and we assumed the constant elevation change rates, these were applied for the DEM values in the locations of OIB/GNSS measurements. The related text, figures and tables have been accordingly revised, the same conclusions are derived.

The updated DEM map (including uncertainty map) can be downloaded from Google drive at https://drive.google.com/drive/folders/1h0-QxAkjGMSc-eqlBBigiqvgp0k-8iIB?usp=sharing at this stage, and we will replace the previous revision in the data storage (i.e., National Tibetan Plateau Data Center, Institute of Tibetan Plateau Research, Chinese Academy of Sciences) after the manuscript revision.

Table 4 (previous Table 3). Comparisons between the ICESat-2 DEM and OIB airborne elevation measurements (including data in areas of low elevation change from 2009 to 2017 and data in the Antarctica from 2018 to 2019) in observed and interpolated areas for individual regions (i.e., the ice sheet and ice shelves). MeD: median deviation, MeAD: median absolute deviation, SD: standard deviation, RMSD: root-mean-square deviation.

	Region	MeD (m)	MeAD (m)	SD (m)	RMSD (m)	Number of used OIB measurement points
Observed	Ice sheet	-0.17	1.21	9.25	9.26	3589087
	Ice shelves	0.59	2.53	14.07	14.09	191754
	Total	-0.15	1.26	9.56	9.57	3780841
Interpolated	Ice sheet	-0.52	2.63	13.30	13.36	1237416
	Ice shelves	0.44	3.00	15.16	15.21	185613
	Total	-0.41	2.67	13.58	13.62	1423029
Overall	Ice sheet	-0.22	1.47	10.44	10.47	4826503
	Ice shelves	0.53	2.75	14.62	14.65	377367
	Total	-0.19	1.54	10.81	10.83	5203870

Table 7 (previous Table 6). Comparisons between the ICESat-2 DEM, ICESat DEM, ICESat/ERS-1 DEM, Helm CryoSat-2 DEM, Slater CryoSat-2 DEM, REMA DEM, TanDEM PolarDEM and

GNSS elevation data in areas of low elevation change from 2001 to 2015.

	MeD (m)	MeAD (m)	SD (m)	RMSD (m)	Number of used GNSS measurement points
ICESat-2 DEM	0.02	0.50	1.59	1.60	
ICESat DEM	-3.79	4.30	10.99	13.10	
ICESat/ERS-1 DEM	-0.75	1.02	2.22	2.32	
Helm CryoSat-2 DEM	0.16	0.89	2.84	2.92	488963
Slater CryoSat-2 DEM	-0.12	0.61	2.41	2.43	
REMA DEM	0.06	0.30	0.78	0.78	
TanDEM PolarDEM	-4.03	4.03	1.52	4.34	

Review:
A new digital elevation model of Antarctica derived from ICESat-2
Shen et.al. 2022

The study presents a new elevation model of Antarctica based on one-year of ICESat-2 observations. The authors provide a specific time-stamped DEM with a final pixel size of 500m, following the same approach as presented by Slater et.al. (2017).

The new DEM is validated against OIB and GNSS data and compared to existing Antarctic DEMs. Results show an improved accuracy compared to DEMs based on Radar altimetry but with less accuracy than DEMs based on Radar interferometry or Stereo-Photogrammetry.

In general, it is an interesting project and worth to be published as ICESat2 provides precise point information with high accuracy and good coverage. This large data base should be used to generate a gridded data product of high quality which is easily accessible and to be used in different applications. The authors did this approach in a comprehensible way. The paper was already submitted to TC and underwent a review process. Most of points of my former review were answered and corrected.

The paper is well structured, methods are explained and figures are of high quality. The validation against OIB and GNSS is clear and shows at least in numbers an improved DEM compared to other Altimeter based DEMs.

Data is accesible via the data link

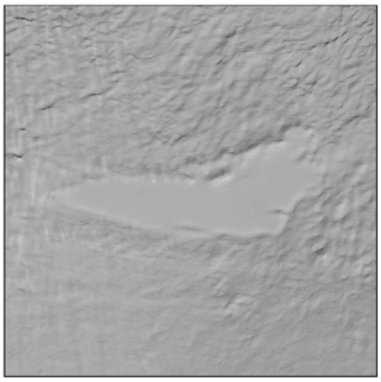
Thank you very much for your positive feedback and advice.

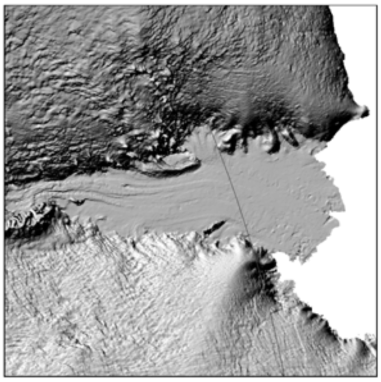
Based on the paper I was now curious to have a look to the DEM itself.
However, after looking at the data I'm a bit disappointed and have some question marks with respect of data quality and usability of the dataset. Attached are two screenshots of the DEM underlain by its hillshade. It can be seen that there are a lots of artefacts visible, even over the flat lake Vostok. Elevation differences at those erroneous pixels are in the order of meters to tenth of meters. In addition a grid like structure is visible in the hillshade or in a roughness image created from the

DEM itself. Furthermore the uncertainty map makes absolutely no sense to me. One can see tracks with uncertainties of 0.01m and between those tracks the values jump to 30 / 50m or more.
I'm wondering why the erroneous pixels are not seen in the statistics of the validation. I think the authors should re-think their methodology in respect to outlier detection as well as the uncertainty. Where are the outliers come from? Why do you have such large jumps in the uncertainty map.
Based on the data set itself I cannot recommend a publication at the current stage as to my opinion this data set is not useful because there are too many erroneous pixels all over Antarctica.

1) about the artefacts
In the previous manuscript, ICESat-2 data in bad quality (based on the data quality flag) are not used and then the estimated elevations due to the poor fitting performances in the grid cells (i.e., Table 2) are removed to ensure the generated DEM quality. Nevertheless, some artefacts still occurred in the DEM map, and these values were derived from the model fitting method (not the interpolation). That is to say, although some quality control criteria have been applied, noises or artefacts cannot be totally removed. In the revised manuscript, to remove additional elevation outliers a 3-standard-deviation filter is applied to the DEM. Visual inspection indicates that a large number of artefacts are removed and the remaining is further removed by using a median filter. After the application of these filters, the ICESat-2 DEM shows a reasonable and acceptable performance. The corresponding hillshade maps in some regions are shown below. We also evaluated the new DEM by comparing to the OIB and GNSS data, similar performances can be found (as listed in the Tables above), this means that the amount of the artefacts in previous DEM is relatively small, and thus has limited effect on the evaluation result.

The related statements have been added into the revised manuscript (see subsection 2.4.2):
'… *Finally, in order to remove additional elevation outliers in the generated DEM, a 3-standard-deviation filter (3 by 3) is firstly applied. Visual inspection indicates that only a small number of anomalous elevations remain and these are further removed by using a 3 by 3 median filter. These quality assurance filters ensure the elevation pattern of the final DEM is smoothed and reasonable.*'.





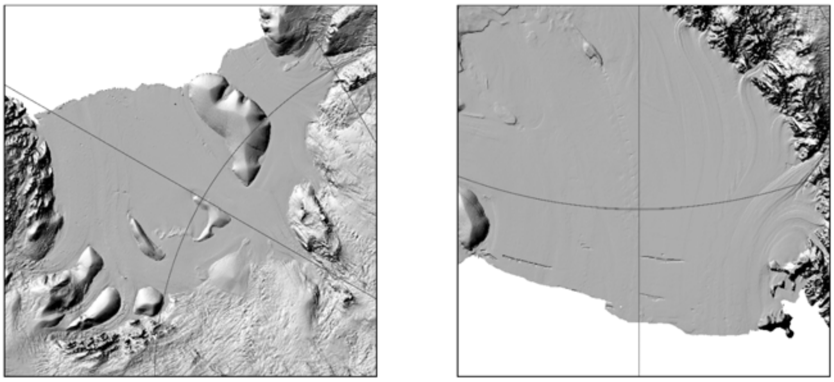


Figure. Shaded relief maps in some regions derived from the ICESat-2 DEM.

2) about the abnormal structure

We have checked the whole generation processes and found a mistake when merging three DEMs (500m DEM, 1000m DEM and interpolated DEM), this caused a slight spatially offset between different DEMs and thus caused the grid like structures in the hillshade map. In the revised manuscript this has been corrected and the corresponding hillshade map is reasonable now (as shown in below).

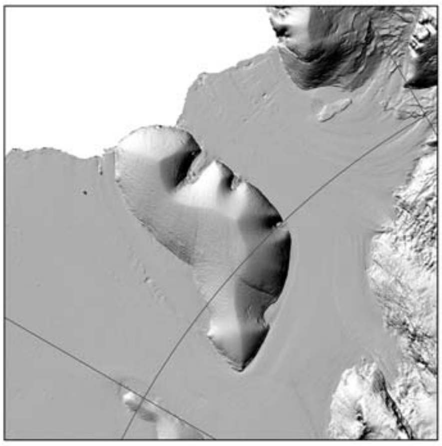


Figure. One example of the shaded relief maps in Antarctica derived from the ICESat-2 DEM.

3) about the uncertainty map

Here DEM uncertainties are calculated for observed and interpolated grid cells, respectively. The observed grid cell uncertainty is derived based on the model fitting performance and the interpolated grid cell uncertainty is calculated from the kriging variance error. As a series of quality control criteria have been applied to remove the unrealistic elevations due to the poor fitting performances in the observed grid cells, the uncertainty values are thus relatively small. While for interpolated grid cells, the elevations are derived based on the kriging interpolation, no valid ICESat-2 measurement points are included in these grid cells, hence the uncertainty values are usually large. We have compared the uncertainty values in the interpolated grid cells to these in CryoSat-2 DEM

(Slater et al., 2018) which also derived from kriging interpolation and also found the similar uncertainty values, this means that our uncertainty estimation method is right.

As our DEM is generated by combining the 500m DEM, 1000m DEM and interpolated DEM, between the tracks the elevations are derived from the interpolated DEM, larger uncertainty values can be found comparing to those tracks (elevations are derived from model fitting method) with small uncertainties. Due to the method difference between the model fitting method and interpolation method, especially in the interpolated grid cells no valid ICESat-2 points can be used, it is natural that their uncertainties have some differences.

Here we also derive an uncertainty map based on the approach in Helm et al. (2014). The OIB elevation data are used as the reference and the elevation differences due to the time difference between OIB data and DEM are corrected based on the elevation-change rates from Smith et al. (2020). The DEM uncertainty is then calculated from surface slope, roughness, number of the used data points (N) and its elevation standard deviation (SD). Due to the method difference we calculate the DEM uncertainty for observed and interpolated grid cells respectively. The surface slope and roughness are directly derived from the ICESat-2 DEM, the slope in one grid cell is derived as the maximum rate of change in elevation from that cell to its eight neighbors, the roughness is derived from the elevation difference between DEM and the smoothed DEM (by applying a 3 by 3 median filter). For observed grid cells, N is the number of the data points in each grid cell used for elevation estimation; for interpolated grid cells, N is derived by counting all data points within a search radius of 10 km, which is the radius used for elevation interpolation. SD is the standard deviation of elevations of these data points. The differences between DEM and OIB elevations are calculated and firstly binned w.r.t surface slope. The slope is divided into 200 bins with an interval of 0.01° (from 0 to 2°), the median and standard deviation are calculated for each bin. This processing method is also applied for other three parameters, an interval of 0.05 m for surface roughness, 250/500 (observed/interpolated grid cells) for N and 0.25 m for SD. For each distribution a 2-order polynomial is fitted by using the different standard deviations of the elevation differences for each bin. The corresponding coefficients are listed in Table 3. This kind of polynomial order ensure a good and robust fitting performance, including for the small elevation differences in flat regions. Finally, the DEM uncertainty is calculated as follows:

$$u = \sum_{i=1}^{4} w_i u_i$$

$$w_i = \frac{1}{s_i \sum_{i=1}^{4} \frac{1}{s_i}}$$

$$s_i = \frac{\sigma_i}{\sum_{i=1}^{4} \sigma_i}$$

$$u_i = b_{i1} x^2 + b_{i2} x + b_{i3}$$

Where u is the DEM uncertainty, w_i is the weighting factor and u_i is the uncertainty for each uncertainty source. s_i is the scaling factor and σ is standard deviation of the difference between data and the polynomial fit. $b_{i\,0\text{-}3}$ are the coefficients for each polynomial fit (as listed in below).

Table 3. The fitting coefficients and weights used for the DEM uncertainty estimation

	Coefficient	Slope	Roughness	N	SD
Observed	b_1	0.13	-0.02	-1.53×10^{-9}	-0.01
	b_2	6.20	0.90	-5.02×10^{-5}	0.42
	b_3	3.37	4.37	12.13	4.85
	Weights	0.45	0.41	0.05	0.09
Interpolated	b_1	0.38	-0.02	2.96×10^{-9}	-4.98×10^{-3}
	b_2	5.04	0.76	-3.60×10^{-4}	0.30
	b_3	5.13	6.56	17.50	7.55
	Weights	0.49	0.37	0.06	0.08

Additionally, by comparing to the OIB or GNSS elevation data, we can estimate the actual ICESat-2 DEM uncertainty as the SD of the differences to OIB or GNSS elevation data. In this estimated uncertainty map (Fig. 5b, as shown in below), a median value of 5.84 ± 5.29 m can be found. The SD of differences to OIB data which obtained in the large scale shows a value of 10.44 m (Table 4, including plenty of measurements in ice sheet margin), while in the ice sheet interior a value of 3.26 m is found (Table 6). Considering the data coverage and surface-slope difference, the estimated uncertainty values can represent the SDs from what is given as OIB, which means that the provided uncertainty estimates are reliable. Small SD value of 1.59 m can be found when comparing to the GNSS data (Table 7) which were obtained in the regions of low slope, this may due to the resolution and measurement accuracy differences between airborne and GNSS data, hence the ICESat-2 DEM uncertainty map may be slightly overestimated and can be assumed as the upper limit.

Slight jumps (< 3 m) can also be found in the current uncertainty map, this is due to the method difference when deriving the elevations and this pattern is consistent to this of elevation source. Due to the method difference between model fitting and interpolation, it is natural that different uncertainty values are found. We think the current uncertainty map (as shown in below) provides more reasonable elevation uncertainties than previous one and use it in the revised manuscript.

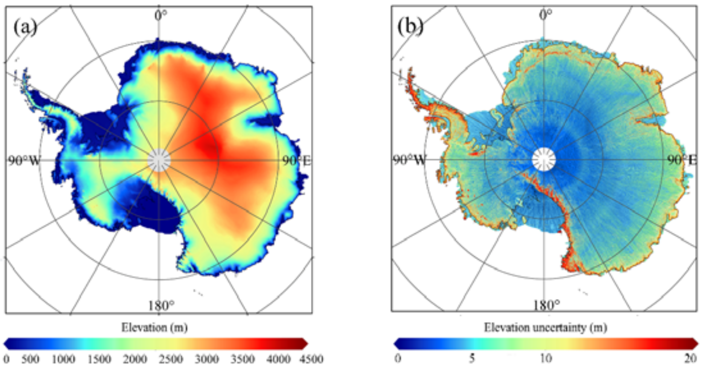


Figure 5. (a) A new DEM of Antarctica at a posting of 500 m derived from ICESat-2, which covers both the ice sheet and ice shelves with the southern limit of 88°S. (b) Map of the ICESat-2 DEM elevation uncertainty.